




University of Applied Sciences  
Swiss College of Agriculture



Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation



Federal Department of Economic Affairs DEA  
Agroscope Reckenholz-Tänikon  
Research Station ART



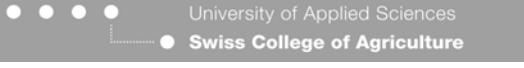
EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

## Organic pollutants in compost and digestate: occurrence, fate and impacts

Thomas Kupper<sup>1)</sup>, Rahel, C. Brändli<sup>2)</sup>, Thomas D. Bucheli<sup>3)</sup>, Carine Stämpfli<sup>4)</sup>, Markus Zennegg<sup>5)</sup>, Urs Berger<sup>6)</sup>, Patrick Edder<sup>7)</sup>, Mandy Pohl<sup>4)</sup>, Fode Niang<sup>4)</sup>, Saverio Iozza<sup>5)</sup>, Josef Müller<sup>8)</sup>, Christian Schaffner<sup>9)</sup>, Peter Schmid<sup>5)</sup>, Sandra Huber<sup>6)</sup>, Didier Ortelli<sup>7)</sup>, Kristin Becker-van Slooten<sup>4)</sup>, Jochen Mayer<sup>3)</sup>, Hans-Jörg Bachmann<sup>3)</sup>, Franz X. Stadelmann<sup>3)</sup>, Joseph Tarradellas<sup>4)</sup>

<sup>1)</sup> Swiss College of Agriculture (SCA), CH-3052 Zollikofen, Switzerland  
<sup>2)</sup> Norwegian Geotechnical Institute (NGI), N-0806 Oslo, Norway  
<sup>3)</sup> Agroscope Reckenholz-Tänikon, Research station ART, CH-8046 Zürich, Switzerland  
<sup>4)</sup> Ecole Polytechnique Fédérale de Lausanne (EPFL), Laboratory of Environmental Chemistry and Ecotoxicology (CECOTOX), Faculty of Architecture, Civil and Environmental Engineering, CH-1015 Lausanne, Switzerland  
<sup>5)</sup> Swiss Federal Institute for Materials Science and Technology (EMPA), Laboratory of Org. Chemistry, CH-8600 Dübendorf, Switzerland  
<sup>6)</sup> Norwegian Institute for Air Research (NILU), NO-9296 Tromsø, Norway  
<sup>7)</sup> Service de Protection de la Consommation, CH-1211 Geneva, Switzerland  
<sup>8)</sup> Fraunhofer Institute for Molecular Biology and Applied Ecology IME, DE-57392 Schmallenberg  
<sup>9)</sup> Swiss Federal Institute of Aquatic Science and Technology, Eawag, CH-8600 Dübendorf, Switzerland, Germany


CODIS2008 27/02/2008
1




University of Applied Sciences  
Swiss College of Agriculture



Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation



Federal Department of Economic Affairs DEA  
Agroscope Reckenholz-Tänikon  
Research Station ART



EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

**Pestizide im See**  
*Vermeidbarer Eintrag via Kläranlagen*  
Schweizer Landwirte versprühen pro Jahr rund 1500 Tonnen Pflanzenschutzmittel auf ihren Wiesen und Feldern. Auch die stolzen Gartenbesitzer verteidigen ihr Obst und Gemüse vehement gegen gefräßige Insekten und Unkraut mit der chemischen Keule. Ein Teil der Wirkstoffe gelangt allerdings in unsere Flüsse und Seen. Vor allem Un-

**Antibiotika allüberall**  
*Negative Folgen der Verbreitung mit Gülle und Mist*  
biotikaresistente Keime stellen für die Humanme-  
problem dar. Besorgniserregend ist vor dies-  
Antibiotika gleichmässig in der Umwe-  
iss diese Praxis weitreichende Fol-

**Unbekannte Chemie im See**  
*Schadstoffe im Wasser – Greifensee und Bodensee im Vergleich*  
Kreuzlingen: Schadstoffe im Wasser – Greifensee und Bodensee im Vergleich  
Im Greifensee haben sich verschle-  
denste Schadstoffe angesammelt.  
Man kann sie nachweisen, aber über  
ihre Wirkung ist noch wenig zu sa-  
gen.

mer grösser werd  
dass die Landw  
dien deuten dara

CODIS2008 27/02/2008
2

University of Applied Sciences  
Swiss College of Agriculture

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation

Federal Department  
of Economic Affairs DEA  
Agrroscope Rechenholz-Tänikon  
Research Station ART

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

 29.01.08

## Zu viel Dioxin im Schweizer Fleisch

**Diese Meldung verdirbt Ihnen garantiert den Appetit: Im Schweizer Fleisch sind hohe Werte des Dioxingifts PCB gemessen worden. Laut dem Bundesamt für Gesundheit (BAG) besteht jedoch kein erhöhtes Gesundheitsrisiko.**

Das Bundesamt untersucht seit 1999 Lebensmittel auf Rückstände von Dioxinen und polychlorierten Biphenylen (PCB). Nun hat es einen Bericht über die bisherigen Ergebnisse verfasst.

Die Rückstände von Dioxinen und PCB seien in den vergangenen Jahren zwar gesunken, schreibt das BAG in einer Mitteilung vom Dienstag. Ein Teil der Stichproben weise aber einen Anteil an PCB auf, der über den Höchstwerten liege, die in der EU seit 2006 für die Summe von Dioxinen und PCB gelten.

CODIS2008 27/02/2008 3

University of Applied Sciences  
Swiss College of Agriculture

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation

Federal Department  
of Economic Affairs DEA  
Agrroscope Rechenholz-Tänikon  
Research Station ART

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

## What are organic pollutants?

- Organic compounds released into the environment
- Adverse effects to living organisms and humans (persistence, bioaccumulative and toxic properties)
- Mostly of anthropogenic origin
- Large variety of compounds and production volumes

CODIS2008 27/02/2008 4



University of Applied Sciences  
Swiss College of Agriculture

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation

Federal Department  
of Economic Affairs DEA  
Agrarische Rechenholz-Tankstelle  
Research Station ART

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

## Pollutants known or supposed to occur in

in compost

in sewage sludge

Polycyclic aromatic hydrocarbons, <b>PAHs</b>	Fragrances
Polychlorinated biphenyls, <b>PCBs</b>	UV-Filter
Polychlorinated dibenzo- <i>p</i> -dioxins and -furans, <b>PCDD/F</b>	Surfactants
Brominated flame retardants, <b>PBDE, HBCD, TBBPA</b>	Pharmaceuticals
Chlorinated paraffins	Natural and synthetic hormones
Phthalates	
Perfluorinated alkyl substances, <b>PFAS</b>	Antibiotics
Pesticides	Veterinary pharmaceuticals

---

CODIS2008 27/02/20087

University of Applied Sciences  
Swiss College of Agriculture

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation

Federal Department  
of Economic Affairs DEA  
Agrarische Rechenholz-Tankstelle  
Research Station ART

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

## Major findings of a literature review

- **Data available: PAHs, PCBs, PCDD/Fs and organochlorine pesticides in compost and feedstock materials**
- **Data not available:**
  - Organic pollutants in digestate and presswater
  - Emerging persistent organic pollutants (POPs)
  - Impacts on soil organisms

---

CODIS2008 27/02/20088

University of Applied Sciences  
Swiss College of Agriculture

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation

Federal Department  
of Economic Affairs DEA  
Agrroscope Reckenholz-Tänikon  
Research Station ART

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

## Issues of the project “Organic Pollutants in Compost and Digestate in Switzerland”

**Monitoring study on compost and digestate derived from source separated input material (Switzerland)**

**Ecotoxicological assessment**

**Study on the fate of organic pollutants during composting and digestion**

---

CODIS2008 27/02/2008 9

University of Applied Sciences  
Swiss College of Agriculture


Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation

Federal Department  
of Economic Affairs DEA  
Agrroscope Reckenholz-Tänikon  
Research Station ART

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

## Target compounds

- **Combustion**

<p>Polyc. aromatic hydrocarbons, <b>PAHs</b>                      Polychlorinated dibenzo-<i>p</i>-dioxins and -furans, <b>PCDD/Fs</b></p>	
--	---

---

CODIS2008 27/02/2008 10

University of Applied Sciences  
Swiss College of Agriculture

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation


Federal Department  
of Economic Affairs DEA  
Agrarische Rechenholz-Tankstelle  
Research Station ART

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE


## Target compounds

- **Combustion**

Polyc. aromatic hydrocarbons, **PAHs**  
Polychlorinated dibenzo-*p*-dioxins and -furans, **PCDD/Fs**


- **Industrial chemicals**

Polychlorinated biphenyls, **PCBs**  
Brominated flame retardants, **PBDE, HBCD, TBBPA**  
Perfluorinated alkyl substances, **PFAS**  
Chlorinated paraffins, **CPs**  
**Phthalates**  
**Nonylphenol**



CODIS2008 27/02/2008 11

University of Applied Sciences  
Swiss College of Agriculture

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation


Federal Department  
of Economic Affairs DEA  
Agrarische Rechenholz-Tankstelle  
Research Station ART

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE


## Target compounds

- **Combustion**


Polyc. aromatic hydrocarbons, **PAHs**  
Polychlorinated dibenzo-*p*-dioxins and -furans, **PCDD/Fs**


- **Industrial chemicals**

Polychlorinated biphenyls, **PCBs**  
Brominated flame retardants, **PBDE, HBCD, TBBPA**  
Perfluorinated alkyl substances, **PFAS**  
Chlorinated paraffins, **CPs**  
**Phthalates**  
**Nonylphenol**


- **Pesticides**

Herbicides, fungicides, insecticides etc.



CODIS2008 27/02/2008 12

University of Applied Sciences  
Swiss College of Agriculture

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation

Federal Department  
of Economic Affairs DEA  
Agrroscope Reckenholz-Tänikon  
Research Station ART

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

## Issues of the project “Organic Pollutants in Compost and Digestate in Switzerland”

**Monitoring study of 9 classes of organic pollutants  
(up to 85 samples analyzed, ~40 plants)**

Ecotoxicological assessment

Study on the fate of organic pollutants during  
composting and digestion

---

CODIS2008 27/02/2008 13

University of Applied Sciences  
Swiss College of Agriculture

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation

Federal Department  
of Economic Affairs DEA  
Agrroscope Reckenholz-Tänikon  
Research Station ART

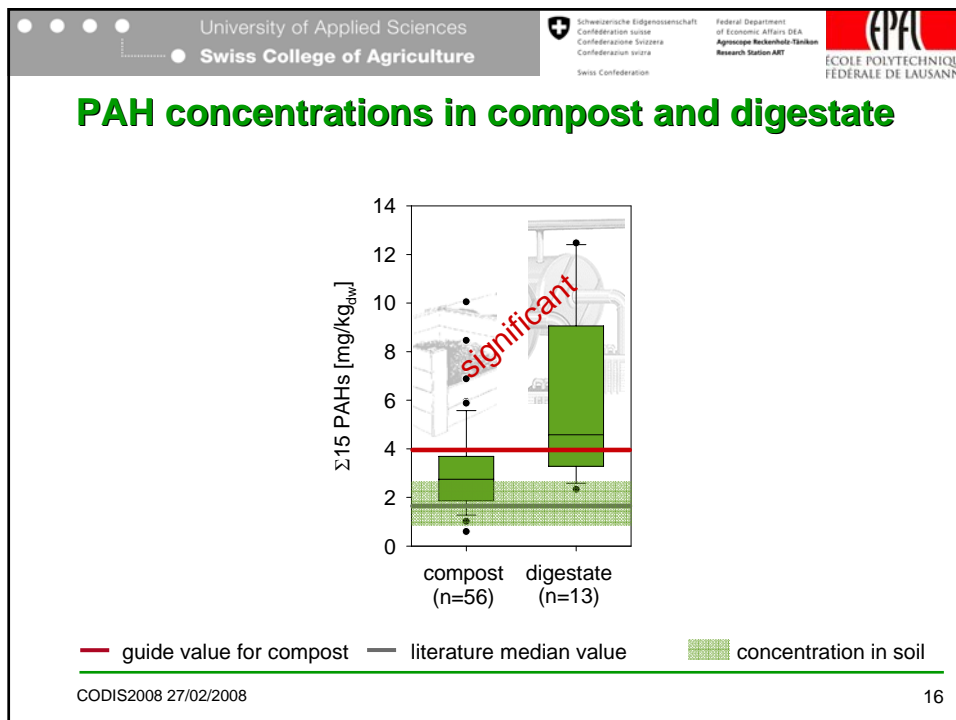
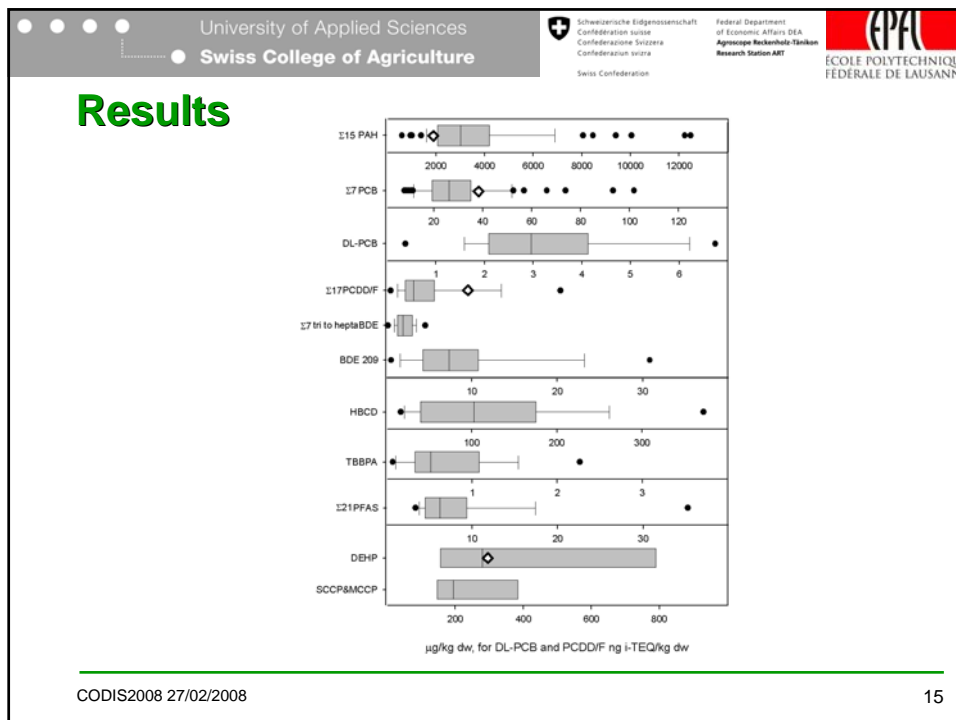
EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

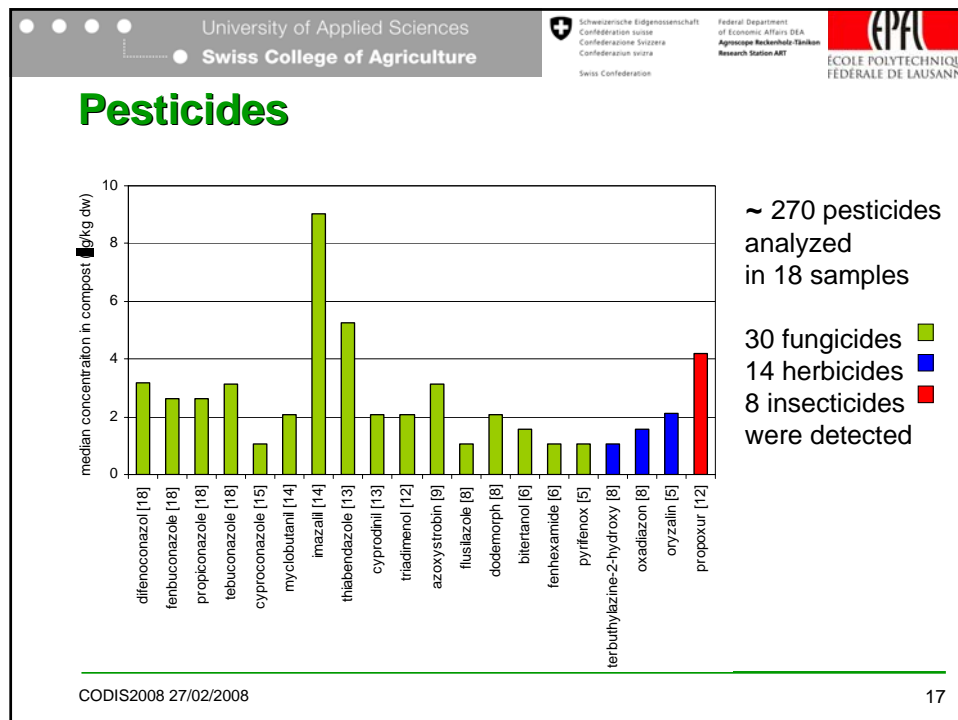
## Sampling design for the monitoring study: Factors hypothesized to influence concentrations in final products

- Processing (aerobic/anaerobic treatment)
- Input material (green waste with/without kitchen waste, i.e. crude organic waste originating from private kitchens)
- Origin of input material (urban/rural)
- Season of input material collection (spring&summer/autumn/winter)

---

CODIS2008 27/02/2008 14





**Issues of the project “Organic Pollutants in Compost and Digestate in Switzerland”**

Monitoring study of 9 classes of organic pollutants (up to 85 samples analyzed, ~39 plants)

**Ecotoxicological assessment**

Study of the fate of organic pollutants during composting and digestion

CODIS2008 27/02/2008 18

University of Applied Sciences  
Swiss College of Agriculture

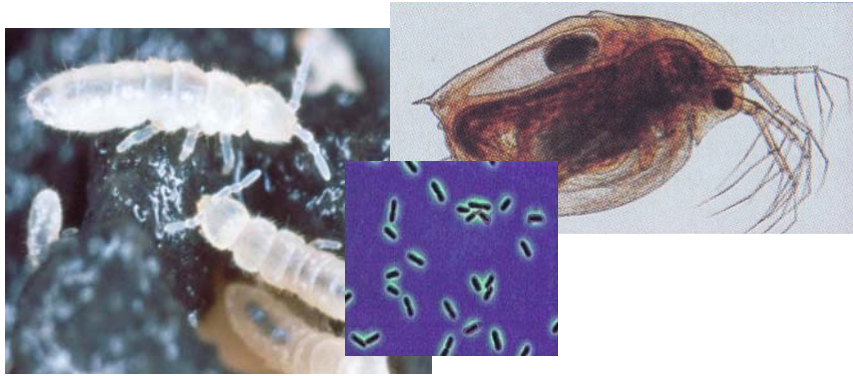
Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation

Federal Department  
of Economic Affairs DEA  
Agrroscope Reckenholz-Tänikon  
Research Station AGT

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

### Test of different methods

- *Collembola Folsomia candida* and *Folsomia fimetaria*
- *Daphnia magna*
- *Vibrio fischeri* (Microtox®)



CODIS2008 27/02/2008 19

University of Applied Sciences  
Swiss College of Agriculture


Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation

Federal Department  
of Economic Affairs DEA  
Agrroscope Reckenholz-Tänikon  
Research Station AGT

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

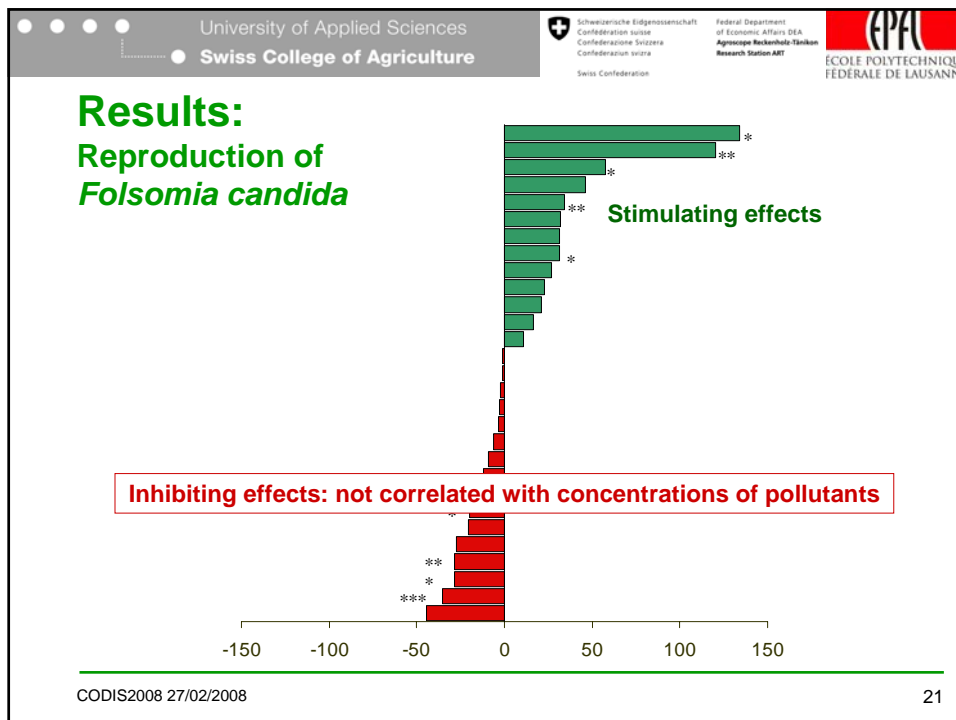
### Tests with *Folsomia candida* (~20 samples)

- Exposure in soil/compost or soil/digestate mixtures  
→ application rate: 100 t d.m./ha/year,  
→ 28 days



- Endpoint: reproduction compared to reference (soil)

CODIS2008 27/02/2008 20



University of Applied Sciences  
Swiss College of Agriculture

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation

Federal Department  
of Economic Affairs DEA  
Agrroscope Reckenholz-Tänikon  
Research Station ART

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

**Issues of the project “Organic Pollutants in Compost and Digestate in Switzerland”**

Monitoring study of 9 classes of organic pollutants (up to 85 samples analyzed, ~39 plants)

Ecotoxicological tests

**Study on the fate of organic pollutants during composting and digestion**

CODIS2008 27/02/2008 22

University of Applied Sciences  
Swiss College of Agriculture

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation

Federal Department  
of Economic Affairs DEA  
Agrroscope Reckenholz-Tänikon  
Research Station ART

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

## Experimental design


- Study on 2 full scale composting plants

Three different open windrows

16 weeks

Compounds studied:

- PAHs
- PCBs
- Pesticides



CODIS2008 27/02/2008 23

University of Applied Sciences  
Swiss College of Agriculture

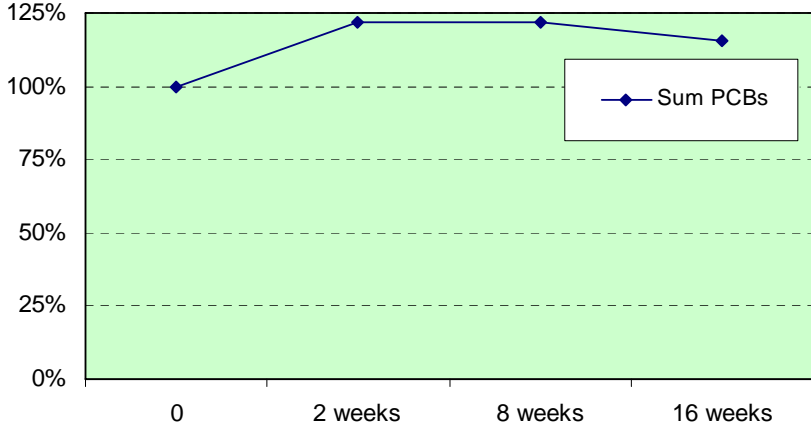
Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation

Federal Department  
of Economic Affairs DEA  
Agrroscope Reckenholz-Tänikon  
Research Station ART

EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

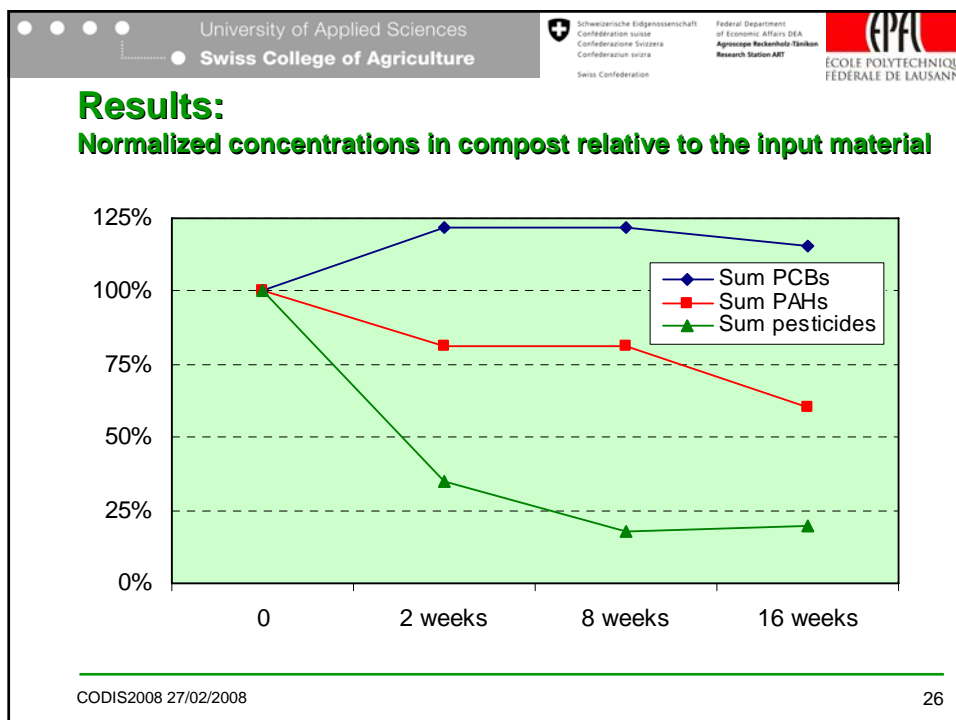
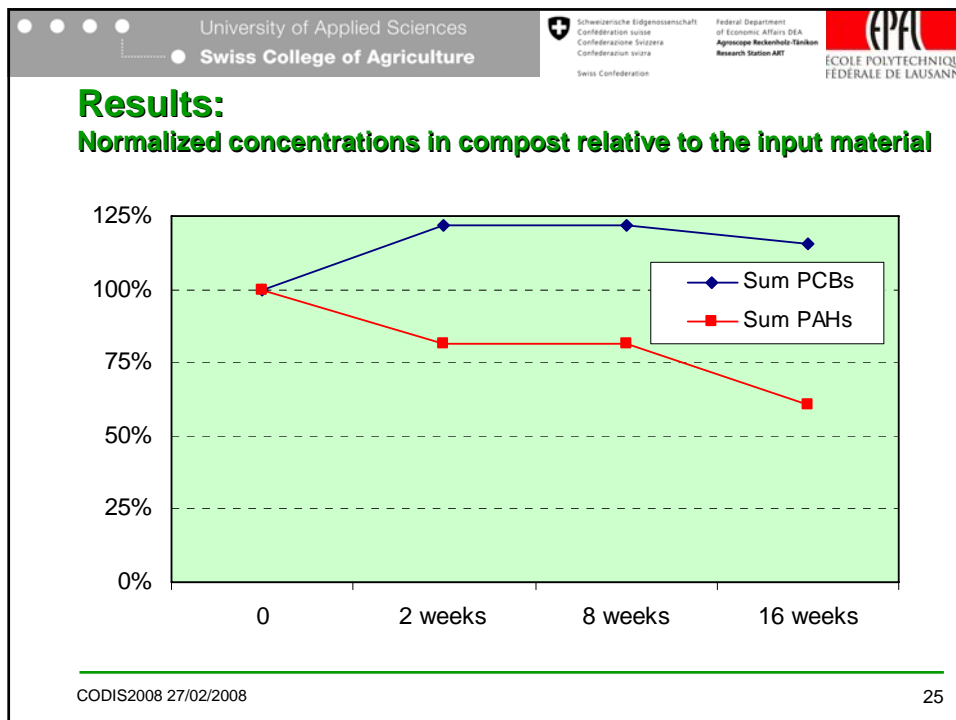
## Results:

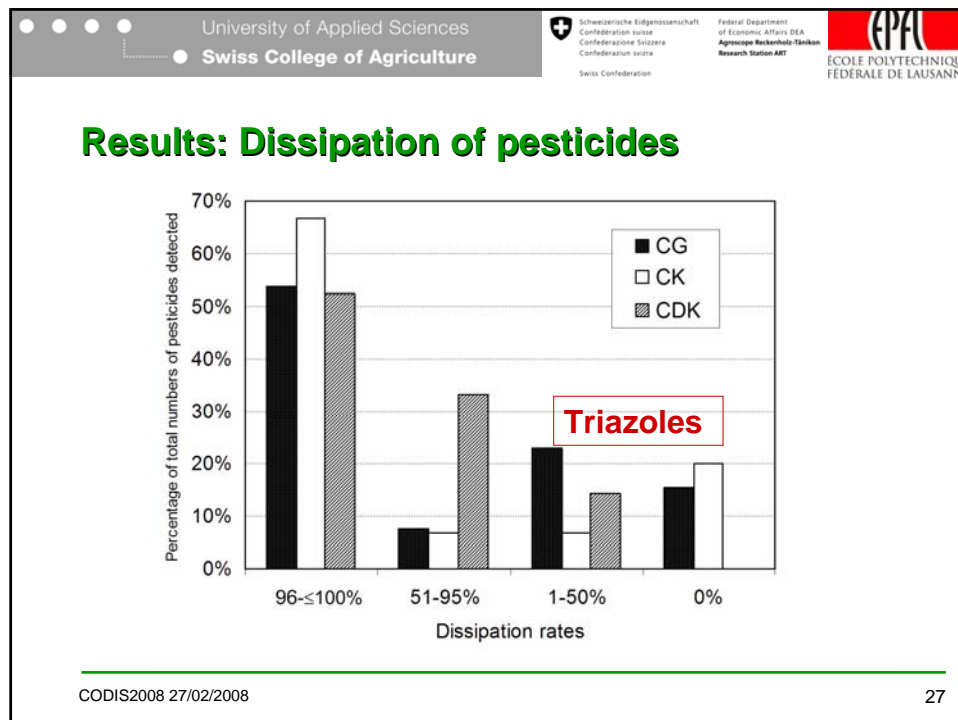
### Normalized concentrations in compost relative to the input material




Time (weeks)	Sum PCBs (%)
0	100
2	120
8	120
16	115

CODIS2008 27/02/2008 24

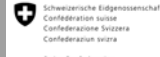





- University of Applied Sciences  
Swiss College of Agriculture
- Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation
- Federal Department  
of Economic Affairs DEA  
Agrroscope Reckenholz-Tänikon  
Research Station ART
- EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE
- ### Conclusions
- Organic pollutants are common contaminants in compost and digestate (also emerging POPs)
  - Concentration levels are low for most of the compounds; relatively high levels observed for PAHs
  - A clear risk for soil organisms was not found
  - Removal of pollutants during composting was insufficient for PAHs and PCBs but high for pesticides
- CODIS2008 27/02/2008
- 28




University of Applied Sciences  
Swiss College of Agriculture



Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation



Federal Department  
of Economic Affairs DEA  
Agrroscope Reckenholz-Tänikon  
Research Station ART



EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

## Outlook

- Identification of sources of PAHs in compost to take appropriate reduction measures
- Appropriate monitoring program for PAHs and emerging contaminants

CODIS2008 27/02/2008
29



University of Applied Sciences  
Swiss College of Agriculture



Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation



Federal Department  
of Economic Affairs DEA  
Agrroscope Reckenholz-Tänikon  
Research Station ART



EPFL  
ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

## Papers

Brändli, R.C., Bucheli, T.D., Kupper, T., Furrer, G., Stadelmann, F.X., Tarradellas, J. 2005. Persistent organic pollutants in source-separated compost and its feedstock materials - a review of field studies. *J. Environ. Qual.* 34(3): 735-760.

Brändli, R.C., Bucheli, T.D., Kupper, T., Furrer, R., Stahel, W., Stadelmann, F.X., Tarradellas, J. 2007. Organic pollutants in Swiss compost and digestate. 1. Polychlorinated biphenyls, polycyclic aromatic hydrocarbons and molecular markers, determinant processes, and source apportionment. *J. Environ. Monit.* 9: 456-464.

Brändli, R.C., Bucheli, T.D., Kupper, T., Mayer, J., Stadelmann, F.X., Tarradellas, J. 2007. Fate of PCBs, PAHs and their source characteristic ratios during composting and digestion of source-separated organic waste in full-scale plants. *Environ. Pollut.* 148(2): 520-528.

Brändli, R.C., Bucheli, T.D., Kupper, T., Stadelmann, F.X., Tarradellas, J. 2006. Optimized accelerated solvent extraction of PCBs and PAHs from compost. *Intern. J. Environ. Anal. Chem.* 86(7): 505-525.

Brändli, R.C., Bucheli, T.D., Kupper, T., Stadelmann, F.X., Tarradellas, J. 2006. Can sources of environmental contamination with PAHs be identified in recipient matrices by concomitant analysis of molecular markers? *Organohalogen Compd.* 68: 292-295.

Brändli, R.C., Bucheli, T.D., Kupper, T., Zennegg, M., Berger, U., Edder, P., Oehme, M., Müller, J., Schaffner, C., Furrer, R., Schmid, P., Huber, S., Ortelli, D., Iozza, S., Stadelmann, F.X., Tarradellas, J. 2006. Organic pollutants in source-separated compost. *Organohalogen Compd.* 68: 863-866.

Brändli, R.C., Kupper, T., Bucheli, T.D., Zennegg, M., Huber, S., Ortelli, D., Müller, J., Schaffner, C., Iozza, S., Schmid, P., Berger, U., Edder, P., Oehme, M., Stadelmann, F.X., Tarradellas, J. 2007. Organic pollutants in Swiss compost and digestate; 2. Polychlorinated dibenzo-p-dioxins, and -furans, dioxin-like polychlorinated biphenyls, brominated flame retardants, perfluorinated alkyl substances, pesticides, and other compounds. *J. Environ. Monit.* 9: 465-472.

Bucheli, T.D., Brändli, R.C. 2006. Two-dimensional gas chromatography coupled to triple quadrupole mass spectrometry for the unambiguous determination of atropisomeric PCBs in environmental samples. *J. Chromatogr. A* 1110: 156-164.

Kupper, T., Bucheli, T.D., Brändli, R.C., Ortelli, D., Edder, P. Dissipation of pesticides during composting and anaerobic digestion of source-separated organic waste on full-scale plants. *Bioresour. Technol.* Submitted


Pohl, M., Staempfli, C., Niang, F., Kupper, T., Stadelmann, F.X., Tarradellas, J., Becker-van Slooten, K. Ecotoxicological tests applied to compost: observation of inhibiting und stimulating effects. *Appl. Soil Ecol.* (in preparation).

CODIS2008 27/02/2008
30

University of Applied Sciences  
**Swiss College of Agriculture**

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra  
Swiss Confederation


Federal Department  
of Economic Affairs DEA  
Agroscope Reckenholz-Tänikon  
Research Station ART




ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

## Acknowledgment

**Founded by:**

 Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra


 Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra


Swiss Confederation


Federal Department of the Environment,  
Transport, Energy and Communications DETEC  
Federal Office for the Environment FOEN

Bundesamt für Energie BFE  
Office fédéral de l'énergie OFEN  
Ufficio federale dell'energia UFE  
Swiss Federal Office of Energy SFOE


**Partners:**

 KAS-ASIC

 Baudirektion  
Kanton Zürich

 FiBL

AWEL Amt für  
Abfall, Wasser, Energie und Luft

 Bundesamt für Landwirtschaft  
Office fédéral de l'agriculture  
Ufficio federale dell'agricoltura  
Swiss Federal Office for Agriculture

**All others who contributed to this project**

**Thanks for your attention!**

---

CODIS2008 27/02/2008

31